Onboard Radar Processing Concepts for the DESDynI Mission

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Abstract - **We are developing onboard processor technology to streamline data acquisition on-demand and reduce the downlink data volume of the L-band SAR instrument onboard the DESDynI mission. Our approach is to determine the types of data processing suitable for implementation onboard the spacecraft to achieve the highest data compression gain without sacrificing the science objectives in each of these areas. The appropriate data processing algorithms and image compression techniques are prototyped with the UAVSAR onboard processor that is currently under development. We are also leveraging the onboard autonomous flight planning software developed for the Earth Observation-1 mission and planned for the HysPIRI mission to enable data acquisition on-demand for specific science objectives. The onboard processor technology will enable the observation and use of surface deformation data and surface change data over rapidly evolving natural hazards, both as an aid to scientific understanding and to provide timely data to agencies responsible for the management and mitigation of natural disasters. In this paper, we will present onboard products that are targeted for rapid response applications such as wild fire, landslide, and flood extent that require a turnaround time of 48 hours or less.**

I. INTRODUCTION

The DESDynI mission combines a repeat-pass interferometric synthetic aperture radar (InSAR) and a multi-beam LIDAR to study deformation, ecosystem system structure, and the dynamics of ice. The L-band polarimetric SAR instrument is expected to operate at high data rate (1 -2 Gbps instantaneous or ~ 350 Mbps orbital average) to meet the high resolution and extensive coverage of the proposed measurements. The current mission design utilizes a 1 Gbps TDRSS link and 8 Tbit onboard data storage to meet the mission objectives with margin. Interferometry objectives for all three science disciplines require this high downlink capability. Appropriate onboard processing technology could reduce onboard data storage and downlink data volume for some non-interferometric data products and expand the utility of the mission by providing rapid response capability.

We have been developing an onboard processor (OBP) concept for rapid response in our NASA funded Advanced Information System Technology task. This OBP concept consists of four major functions:

1. Control processor – ingest ephemeris data, generate processor parameters, retrieve reference data set if needed for repeat-pass product generation such as change detection.
2. SAR image formation – form single look compressed (SLC) image and interferogram with reference SLC image if requested.
3. Image compression – compress SLC image or interferogram with traditional image compression algorithms.
4. Product generation – generate geophysical products such as forest biomass, flood scene map, sea ice classification, and change detection.

Figure 1 shows the OBP scenario for DESDynI mission. The OBP can operate in one of two modes. When no onboard products are to be generated, as in the case of repeat pass InSAR observations, we compress the SAR image or interferogram in order to reduce the downlink data volume by a factor of 10. If onboard products are generated for rapid response applications, we can reduce the downlink volume by a factor of 1000 or more, which will allow us to downlink the results via Direct-Broadcast Satellite (DBS), which has a downlink throughput of 15 Mbps. Using the DBS downlink channel will make targeted, critical information readily available to disaster response agencies in a timely manner.

The processor architecture, as shown in Figure 2, is based on the OBP developed for UAVSAR, the airborne repeat-pass interferometric synthetic aperture radar testbed [1]. We chose a hybrid architecture where we use a general purpose microprocessor for data-dependent calculations that are performed occasionally and all other arithmetic operations that operate on every radar pulse in the field programmable gate array (FPGA). We demonstrated real-time SAR image formation with the custom FPGA processor board. Two FPGA processor boards are built to process data from two polarization channels or two interferometric channels at the

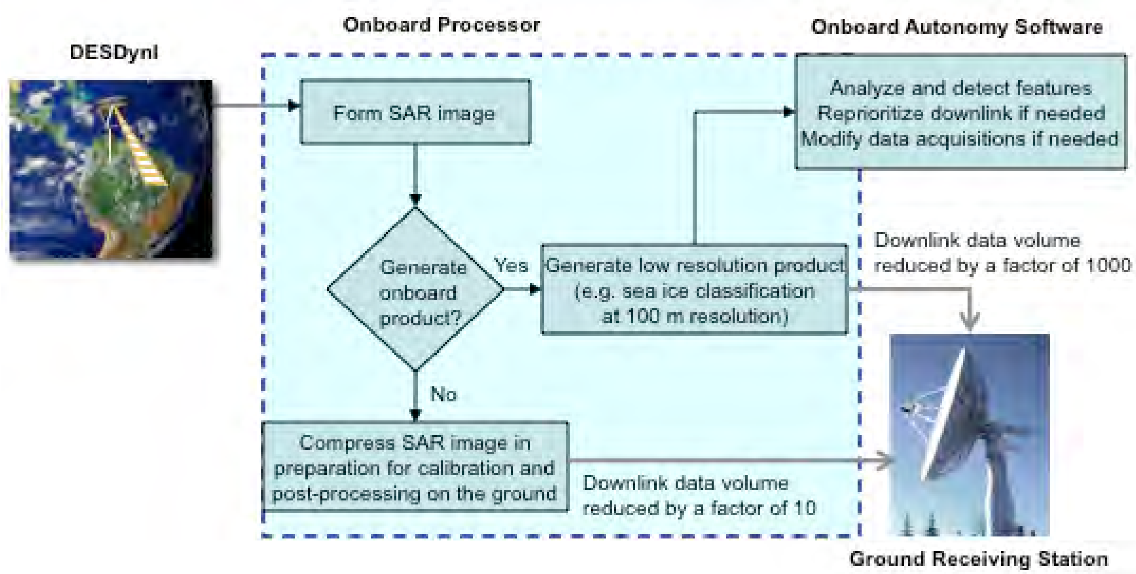

Fig. 1. OBP scenario for DESDynI mission's L-band polarimetric repeat-pass InSAR instrument.

same time. The availability of dual-polarized data and repeat-pass interferometric data enable us to generate quick-look science products based on unsupervised classification of polarimetric data and change detection respectively. In this paper, we present example data products that can be generated onboard the spacecraft for rapid response applications.

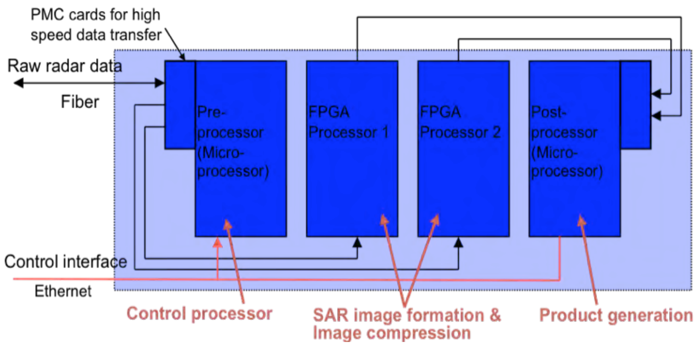

Fig. 2. UAVSAR OBP hardware architecture, where general purpose microprocessors are used for control processing and product generation and custom FPGA processor boards are used for SAR image formation and image compression.

II. RAPID RESPONSE APPLICATIONS

A. Surface Water Mapping and Flood Detection

Calm water surfaces can be clearly distinguished from most land backgrounds based on a single SAR channel due to its low backscatter values [2]. Analysis of an HV L-band backscatter image shows dramatic attenuation from open bodies of water, or flooded areas. Thresholding of backscatter magnitude – tuned either from calibration parameters of the radar, or via normalization of the image –followed by a number of Gaussian filters would reliably filter out small point attenuations, and coalesce larger expanses. These larger expanses could then be clustered by a continuity sieve and geolocated by a centroid of the cluster. This algorithm relies on masking the input image towards flood prone areas and against false positives from high attenuation features such as rough topography that can cause "shadowing" effects. This algorithm, tested with UAVSAR data, successfully detected large ponds formed in the bottom of large rock quarries in the San Gabriel Valley following heavy rains.

B. Ice vs. Land/Water Detection for Glacier Monitoring and Sea Ice Tracking

Polarimetric SAR data have been used for sea ice detection and classification since this was first demonstrated with SIR-C data acquired in 1994 [3]. HV-intensity and HH/VV ratio and anisotropy have been used for sea ice edge/open water detection. Change detection techniques have been used to monitor glacier recession with satellite SAR data since the ERS-1 mission [4]. Figure 3 shows a UAVSAR image acquired over Greenland's Kangerlugssuaq glacier in May 2009. The grounding line is clearly visible in the image. These products would be high value rapid response products for use in glacier monitoring and in tracking sea ice.

C. Forest Fire Detection – Crown Weight Difference

Another rapid response application is tracking of forest fires via biomass measurements. A number of algorithms exist based on canopy/crown biomass weight estimation [5]. We have been evaluating such algorithms to monitor forest fire progression during actual fire events, delivering products for assistance in fighting and mitigating fires. Such products can also be used in rehabilitation efforts by providing valuable information on burn extent and severity. Figure 4 is a three-polarization overlay UAVSAR image of the Big Sur fire acquired in July 2008, showing the fire scars from the June 2008 fire.

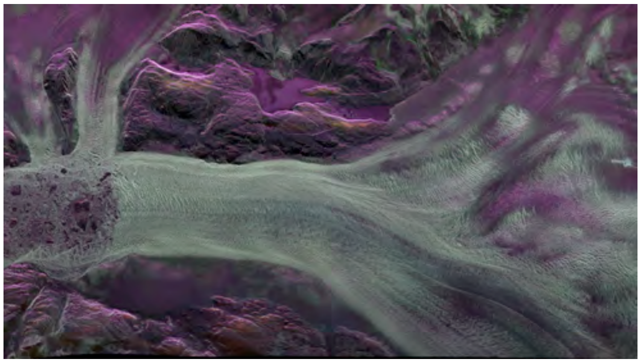

Fig. 3. Three-polarization color overlay image of Kangerlugssuaq glacier where LHH, LHV, and LVV are represented in red, green, and blue respectively. The grounding line is clearly visible in this UAVSAR image acquired in May 2009.

Fig. 4. Three-polarization color overlay image of Big Sur fire acquired by UAVSAR in July 2008. Fire scars are shown in purple, where HH and VV polarizations are dominant due to surface scattering.

III. UAVSAR AND DESDYNI AUTONOMOUS RESPONSE

With the ability to generate real-time data products, UAVSAR attains the potential of a reactionary or smart agent with self-acquired data as closed loop stimulus. Together with real-time planning software, the agent can safely modify its planned operations to further investigate observed phenomena, or act on other information provided from other systems, contingent upon operating within the constraints of the system platform. This project adopted and integrated ASPEN/CASPER to generate new flight-plans on-board for UAVSAR to execute in response to real-time data. Availability of onboard planning would also allow DESDynI to replan future observations similar to the Autonomous Sciencecraft on EO-1 [6].

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